Energy Management Module for Mobile Robots in Hostile Environments

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In hostile environments at CERN and other similar scientific facilities, having a reliable mobile robot system is essential for successful execution of robotic missions and to avoid situations of manual recovery of the robots in the event that the robot runs out of energy. Because of environmental constraints, such mobile robots are usually battery-powered and hence energy management and optimization is one of the key challenges in this field. The ability to know beforehand the energy consumed by various elements of the robot (such as locomotion, sensors, controllers, computers and communication) will allow flexibility in planning or managing the tasks to be performed by the robot.

Robots with auto-recharging techniques such as in [1] cannot always be used in industrial or hostile applications as the environments are not usually designed to be robot friendly. Liu et al. [2] present an energy breakdown table of a Mars rover. However, they do not build power models for each component. Power models were used in [3] to optimize the deployment of robots under energy and timing constraints. Analysis of previous studies suggests that there is no common approach for creating power and energy consumption models of various components irrespective of the type of mobile robot. Hence, a generic modular approach for building power models and determining the energy consumption of a mobile robot is proposed in this paper.

The time-stamped instantaneous battery voltage and total current used by the robot is used to build the power models (Fig. 1, right). The energy consumption for each component is calculated by multiplying the power value of the component (from the power model) by the amount of time the component is used. $E = \int P(t)\,dt$.

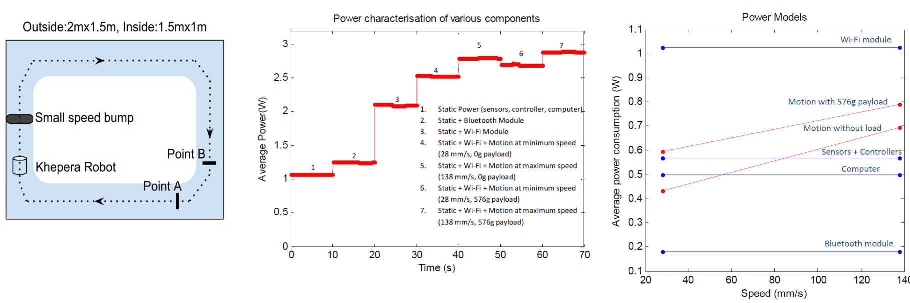

Fig. 1. Path taken by the robot (left), Power characterization of different components (center), Measured linear power models for different components in a Khepera III robot (right)

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A Khepera III mobile robot was used for initial experiments. Simple algorithms for deriving the power models from a simple basic series of operations (Fig. 1, center) and calculating the energy consumption of each component were written in MATLAB and tested with the robot's datasets created during the experiments. Simple experiments of the robot going from point A to point B (Fig. 1, left) in the chosen speed range were performed (Fig. 2, left) and the energy consumption by different components are shown in Fig. 2, right. Different tasks or missions exhibit different energy consumption behavior; nevertheless, the energy characterization will allow the operator to optimize the energy consumption. For instance, using Bluetooth instead of Wi-Fi and using the highest locomotion speed possible, the robot can save up to 81% energy compared with the worst case.

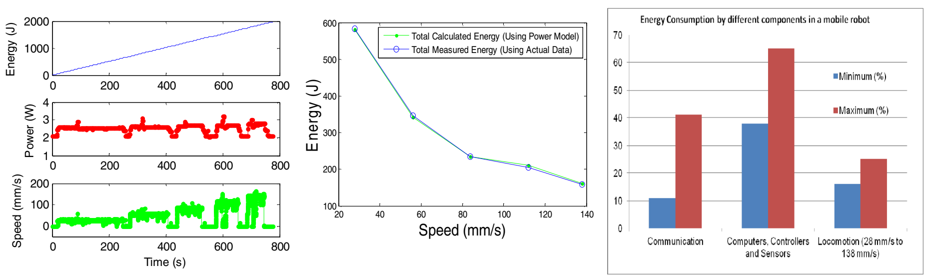

Fig. 2. Measured speed, power and energy values (left), Comparison of Calculated Energy and Measured Energy values (center), Energy consumption by different components (right)

This study is based only on a small robot and hence for bigger robots, other effects have to be considered such as non-linear power models and battery lifetime. The energy needs calculated using power models were compared with the actual energy values (Fig 2, center) and the proposed method demonstrated high accuracy (≥ 96%) during tests. Hence, this approach can be used in energy planning to increase the safety and reliability to the robot in hostile environments. Further work will include testing this algorithm on other robots with a large number of components to predict the repeatability of using energy models and to ensure the modularity and usability of this approach. Future plans include integration of this method in simulators such as Player/Stage and also working on applications of using such energy management module in fault detection and energy optimization.

References

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